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Developments in Particulate Control for Coal-Fired Power Plants

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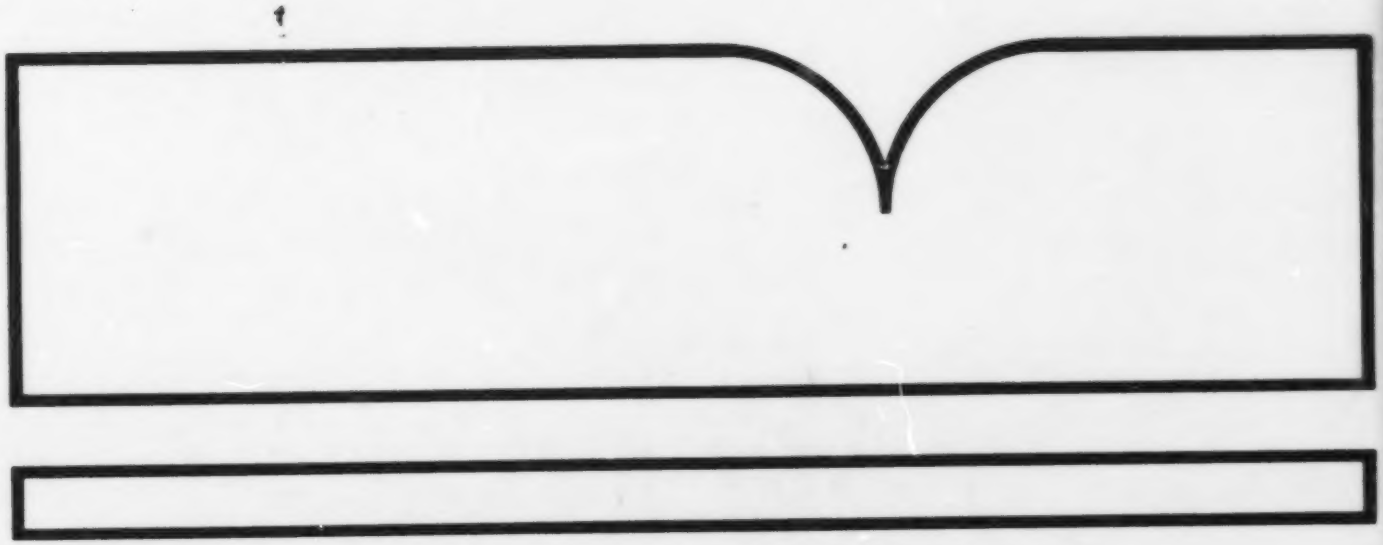

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16. ABSTRACT The paper discusses recent developments in particulate control for coal-fired power plants. The developments are responding to a double challenge to conventional coal-fired power plant emissions control technology: (1) lower particulate emissions require more efficient control devices; and (2) lower SOx emissions achieved with low-sulfur coal combustion are coupled with poor electrostatic precipitator (ESP) performance. Possible solutions to these problems include conditioning, hot-side ESPs, and novel ESPs. Novel ESPs include the Buell Trielectrode ESP, the University of Denmark Pulse Generator/ESP, and the Cold Electrode ESP. Also under development are two-stage ESPs using novel charging sections; e.g., the Southern Research Institute Precharger, the APS High Intensity Ionizer, and the University of Tokyo Boxer Charger. As an important alternative to ESPs, baghouses have shown general success in controlling emissions from coal-fired power plants. Current baghouses are installed at the Cameo, Harrington, Holtwood, Kramer, Martin Drake, Nucla, and Sunbury power stations. When operating properly, baghouses can limit emissions to <5 mg/cu nm at pressure drops of <2 kPa. Not all baghouses have been completely successful; e.g., both high pressure drop and bag loss have been experienced at the Harrington station.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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Journal Article

FLUE GAS
DESULFURIZATION:

Developments in Particulate Control For Coal-Fired Power Plants

Both fabric filters and scrubbers are gaining acceptance. Full load pressure drops are now being maintained under 2 kPa.

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Particulate control for coal-fired power plants has been developed primarily in response to changes in the new source performance standards for both sulfur oxides and particulates. With the first restrictions on SO_x emissions came fuel switching from high sulfur to low sulfur coal. But in many cases, using low sulfur coal reduced the collection efficiency of electrostatic precipitators designed for particulate control on coal-fired boilers (*1*). The theory was that the high sulfur coal produced sulfur trioxide which condensed on fly ash particles, forming sulfuric acid and lowering resistivity. Lower resistivity provided better performance, because the electrostatic precipitator can operate at a higher current without excessive voltage differentials. The presence of these across the dust layer on the collection plate can cause back-corona and loss of efficiency. Therefore, electrostatic precipitators had to be developed to deal with high resistivity particulate emissions, especially fly ash. Initially, the options considered were conditioning and changes in the operating temperature.

In its simplest form, conditioning adds back SO_3 to the power plant flue gas in advance of the precipitator, to lower resistivity and restore the efficiency achievable on a high sulfur fly ash. One recent study on a plant burning 1% sulfur coal determined that without conditioning, resistivity was 1.7×10^{11} ohm/cm, and the overall precipitator collection efficiency was 80.2%. With SO_3 conditioning, the resistivity was lowered to 4.7×10^{10} ohm/cm, and the collection efficiency rose to 94.9%—the design efficiency when burning high sulfur coal (*2*).

Other forms of conditioning may also change resistivity, affect the space charge, or cause small particles to agglomerate to more easily captured large particles. Many conditioning agents are proprietary formulations, but often rely on the direct or indirect formation of SO_3 to lower resistivity. The environmental impact of conditioning agents has not been determined and remains a question in the use of this method.

A second option is to change the operating temperature of the electrostatic precipitator. At typical stack temperatures (150°C), the resistivity is the highest and can be lowered either by cooling the flue gas before the precipitator or by placing the precipitator in a hotter region, such as before the air preheater. The latter course of action has been preferred. At hot-side temperatures (350°C), resistivity is lowered because of conduction through the fly ash, primarily by means of sodium ions. However, "hot-side" precipitators can also lose efficiency because of electrical characteristics similar to back-corona—even though the resistivity is low, such as 5×10^9 ohm/cm (*3*). For coals low in sodium as well as low in sulfur, use of hot-side electrostatic precipitators may not solve loss of collection efficiency problems associated with coal switching from design to actual or during operation. Conditioning with sodium carbonate is possible, providing the slagging characteristics of the fly ash are not changed to cause boiler tube deposits.

From the above discussion, it is clear that problems remain in the use of electrostatic precipitators on coal-fired power plants, although historically, precipitators have been the control device of choice. Recent developments have focused on new precipitator designs to accommodate high resistivity fly ash and on alternative control devices.

On June 11, 1979 the Environmental Protection Agency (EPA) promulgated revised particulate standards for electric utility steam-generating units with heat input of greater than 73 MW (*4*). Emissions less than 13 ng/J (0.03 lb/million Btu) are required, a significant reduction from the previous standard of 43 ng/J (0.1 lb/million Btu). This has greatly affected the consideration of alternative control devices. Fabric filters easily achieve high levels of collection efficiency, while scrubbers require more energy to improve performance (*5*). Hence, attention has shifted to applying fabric filters to power plants. Research on scrubbers has sought performance improvements with more economical energy inputs, such as those with flux force/condensation or electrostatically augmented scrubbing.

Changes in precipitator design can either isolate or not isolate the charging process. Examples of the former are the APS High Intensity Ionizer, the Southern Research Precharger, and the University of Tokyo Boxer Charger. Examples of the latter are the Buell Trielectrode Electrostatic Precipitator, the University of Denmark Pulse Generator/Precipitator, and the Cold Electrode Electrostatic Precipitator.

The purpose of isolation is to use high fields or AC fields for more effective charging. Particles would be collected in a separate zone where the current could be kept small to avoid back-corona problems. Because of the separate zones for charging and collection, this approach has been called a two-stage precipitator. Ordinarily, the charger is placed ahead of the collector and is called a precharger. The Southern Research unit is a new design, because it uses a third electrode in the precharger to prevent back-corona problems. The third electrode is a grid near the grounded electrode. It carries the same sign as the discharge electrode. If back-corona occurs, the charges of opposite sign generated are collected by the grid. The space between the discharge electrode and the grid is maintained at a high level of unipolar charge, for good charging at all times.

The Boxer Charger is also a precharger but differs from conventional designs because it uses AC fields. In its simplest form, the Boxer Charger has two sets of discharge electrodes on either side of the gas stream. During the first half of the cycle, the first set of electrodes would be discharging and the second set at ground potential. During the second half of the cycle, the conditions reverse. There are two advantages of this technique. First, the particles are impacted by ions from two directions. Second, neither set of electrodes maintains ground potential long enough to build up a dust layer giving back-corona.

The APS High Intensity Ionizer was also originally conceived as a precharger, but a recent study shows it will be effective if placed somewhere within the electrostatic precipitator (*6*). For that application, efficiency could be greatly increased if the high intensity ionizer replaced a section of the precipitator approximately one-third of the way down from the entrance.

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Changes in precipitator design not associated with separate charging sections usually involve modifying the electrodes. The Buell Trielectrode Electrostatic Precipitator (TEP) uses a third, nondischarging electrode to maintain the field for collection. Meanwhile, the voltage through the collected dust layer has time to decay before reaching back-corona levels. The third electrode is placed in line and alternating with the discharge electrodes. Discharge electrodes are pulsed for a small percentage of the time (e.g., 4%), and the third electrode operates over the remainder, except for a very short transition time. In the laboratory data, the TEP maintained collection efficiencies greater than 90% for resistivities as high as 10^{13} ohm/cm. With increasing resistivity, data for the conventional precipitator lost efficiency down to 30% (*7*).

Another solution to high resistivity particulate collection with electrode modification is the Cold Electrode Electrostatic Precipitator (CEEP). CEEP uses a series of rectangular ducts for the collecting electrode, which is cooled internally by 70°C water. As noted above, lowering the temperature reduces the resistivity to avoid back-corona. Another novel feature of the CEEP is that the collecting electrodes are scraped instead of rapped.

An electrode modification combined with a pulse generator has been investigated by the Technical University of Denmark. In a conventional electrostatic precipitator configuration, the discharge electrode is specially designed with rounded peaks at intervals down the length of the electrode. The usual DC voltage is supplemented with pulses to improve particle charging and current distribution. Full scale experiments on the Danish precipitator show reductions in penetration as high as a factor of 2 for 10^{13} ohm/cm particulate emissions (*8*).

Alternate technologies

Both fabric filters and scrubbers are alternatives to electrostatic precipitators for power plant particulate control. Most operating scrubber installations are designed to remove both SO_2 and particulates. Across the nation, nine utility companies have one or more units using this approach. However, five utility companies have scrubbers used for particulate collection only. The stations using such scrubbers are Arapahoe, Cherokee, Clay Boswell, Dave Johnston, Four Corners, Lewis and Clark, Syl Laskin, and Valmont. These stations operate their scrubbers with system pressure drops ranging from 1 to 7 kPa and outlet particulate concentrations ranging from 10 to 23 mg/nm^3. To achieve the new standard of 13 ng/J, we expect system pressure drops in excess of 7 or 8 kPa will be required.

To reduce the power requirements and still meet high collection efficiencies, EPA has studied flux force condensation scrubbers and electrostatically augmented scrubbers. Various systems of electrostatically augmented scrubbers have been described elsewhere, with the conclusion that power requirements could be effectively reduced (*9*). The reduction can be very high (e.g., 80%) but the systems with very low power requirements also need residence times as long as 8 sec. Since this is the order of magnitude of electrostatic precipitator residence times, only careful case by case economic comparisons will determine the optimum approach.

Flux force condensation scrubbers are also capable of high collection efficiencies. By condensing moisture from a supersaturated gas, small particles are grown and/or transported to cold water droplets by diffusiophoresis or thermophoresis. Small particles not transported to a collector by flux forces are gathered easily by the scrubbing action, since they have grown by condensation to collectible size. Flux force condensation scrubbing remains to be demonstrated on a coal-fired boiler.

Fabric filters on coal-fired boilers are increasing in use; interest is great because of inherent high collection efficiencies. Within power companies in the U.S., stations now using fabric filters include Cameo, Harrington, Holtwood, Karmer, Martin Drake, Nucla, and Sunbury. Typical is Cameo in the Public Service Company of Colorado system, and the baghouse is on Unit No. 1, rated at 22 MW. The baghouse was designed for a 2 g/nm^3 inlet concentration and a pressure drop of 1.75 kPa with 2 compartments out. The coal used is from Routt or Mesa County, Colorado, and has 4 to 18% ash and 0.3 to 0.7% sulfur. The fly ash produced has a mass median diameter of approximately 12 μm.

The baghouse was built by Carborundum with reverse air cleaning a gross air-to-cloth ratio of 1.92 to 1, which rises to 2.20 to 1 with one compartment out and 2.57 to 1 with two compartments out. The bags are a twill weave fiberglass with 10% DuPont Teflon B treatment. The unit was placed in operation late 1978. After initial difficulties such as loose retaining clamps were resolved, emissions were limited to less than 3 mg/nm^3 and 2 to 4% opacity (*10*). A similar success story has developed at the Martin Drake Plant, operated by the City of Colorado Springs, Department of Public Utilities. In this case, the baghouse was built by Buell for Unit No. 6, rated at 85 MW. The baghouse is reverse air-cleaned with treated glass bags. Again both pressure drop and collection efficiency performance have met guarantees. Other long running success stories have been reported elsewhere for Holtwood, Kramer, and Sunbury stations (*11*).

But not all installations have complete success. Specifically, the Harrington station has experienced pressure drops as high as 3.0 kPa and bag loss rates as high as 10% in 3 months. Their baghouse is on Unit No. 2, rated at 350 MW. The coal is nominally 5.5% ash and 0.3% sulfur. The gross air-to-cloth ratio is 3.16 to 1, which rises to 3.27 to 1 with one compartment out. Bag failures were usually pinholes near the cuff, but massive bag failures were also encountered. Initially, the baghouse used fiberglass bags with silicone/graphite finish. Currently in use are new bags with Tri-Treat finish on the east side of the house and Teflon B finish on the west. Full load pressure drops are now being maintained under 2.0 kPa. #

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